

(b) at least two of:

(i) crystalline  $\text{Al}_2\text{O}_3$ ,

(ii) first crystalline complex  $\text{Al}_2\text{O}_3 \cdot \text{Y}_2\text{O}_3$ , or

(iii) second, different, crystalline complex  $\text{Al}_2\text{O}_3 \cdot \text{Y}_2\text{O}_3$ , wherein said fused, crystalline abrasive particles comprise at least 50 percent by volume, based on the total metal oxide volume of the respective particle, of said eutectic material, wherein the abrasive particles comprising, on a theoretical oxide basis, at least 40 percent by weight  $\text{Al}_2\text{O}_3$ , based on the total metal oxide content of the respective particle, and wherein a portion of said complex  $\text{Al}_2\text{O}_3 \cdot \text{Y}_2\text{O}_3$  Y cations are substituted with at least one cation selected from the following cations: Ce, Dy, Er, Eu, Gd, Ho, La, Lu, Nd, Pr, Sm, Th, Tm, and Yb.

15. A plurality of abrasive particles having a specified nominal grade, said

plurality of abrasive particle having a particle size distribution ranging from fine to coarse, wherein at least a portion of said abrasive particles is a plurality of fused, crystalline abrasive particles, said fused abrasive particles comprising at least 20 percent by volume, based on the total metal oxide volume of the respective particle, eutectic material, wherein said eutectic material comprises eutectic of at least:

(a) crystalline  $\text{ZrO}_2$  and

(b) at least two of:

(i) crystalline  $\text{Al}_2\text{O}_3$ ,

(ii) first crystalline complex  $\text{Al}_2\text{O}_3 \cdot \text{Y}_2\text{O}_3$ , or

(iii) second, different, crystalline complex  $\text{Al}_2\text{O}_3 \cdot \text{Y}_2\text{O}_3$ , wherein said fused, crystalline abrasive particles comprise at least 50 percent by volume, based on the total metal oxide volume of the respective particle, of said eutectic material, wherein the abrasive particles comprising, on a theoretical oxide basis, at least 40 percent by weight  $\text{Al}_2\text{O}_3$ , based on the total metal oxide content of the respective particle, and wherein a portion of said complex  $\text{Al}_2\text{O}_3 \cdot \text{Y}_2\text{O}_3$  Y cations are substituted with at least one cation selected from the following cations: Fe, Ti, Mn, V, Cr, Co, Ni, Cu, Mg, Ca, and Sr.

#### Remarks

Claims 13-15 have been amended. Claims 2-28, 30-35, 41, and 44-89 are pending.

Examination and reconsideration of the application as amended is requested.

**New Matter Rejection**

It is stated in the Office Action that:

The amendment filed 1/22/02 to page 41 of the specification (which is the same as the amendment filed 12/28/00) is objected to under 25 U.S.C. 132 because it introduces new matter into the disclosure. ... The added material which is not supported by the original disclosure is as follows:

The amendment to page 41, line 22 which changed the width of the phases in figure 9 from "up to about 1 micrometer" to "up to about 2 micrometers" is new matter because the specification does not provide support for this. Applicant states that support for this amendment can be found in figure 9. The examiner fails to see how this figure provides support for this amendment.

Applicants state that the amendment filed 1/22/02 amends the paragraph on page 41 to define the original, as filed text. To the contrary, the original, as filed text states that the section as a size up to about 1 micrometer. The amendment in question defines a size of "up to about 2 micrometers" which is not the originally filed text. Applicants also state that the scanning electron photomicrograph speaks for itself (i.e. assuming this is referring to the size). The examiner disagrees because a size can not be deciphered from this photomicrograph.

**Applicant is required to cancel the new matter in the reply to this office Action.**

Although it was intended in the previous response to amend the text in question to provide the original, as-filed, text, it appears that the amendment in the previous response did not do so. Hence in the instant paper the intended amendment is made, which is the amendment requested by the Examiner. Although there is disagreement in the current Office Action that the widths of the phases referred to on page 41, lines 21-22 of the specification cannot be determined from FIG. 9, resolution of such disagreement is not necessary in view of the instant amendment and that FIG. 9 remains part of the disclosure of the instant application.

**§ 112, Second Paragraph Rejections**

-Previous Indefinite Rejection:

Claims 46, 50, 51 and 52 continue to be rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicant regards as the invention.

Claims 46 and 52 are said to be indefinite because it is alleged that "the converting step" is unclear. The converting step is said to be indefinite because page 18, line 10 to page 20, line 3 does not clearly define that the limitation defined on these pages are the converting step.

Referring to pages page 18, line 10 to page 20, line 3, such disclosure includes (a) cooling the melt and then crushing the resulting solid material to provide abrasive particles or (b) pouring the melt into molds having the desired size and shape of the abrasive particles and then cooling the melt. The "converting" the melt into said fused, crystalline abrasive particles is intended to generically cover various ways that the melt can be transformed into the abrasive particles, including by cooling the melt and then crushing the resulting solid material to provide abrasive particles or by pouring the melt into molds having the desired size and shape of the abrasive particles and then cooling the melt. Hence it is submitted that the use of the term "converting" in claims 46 and 52 is clear.

In summary, Applicant submits the rejection of claims 46 and 52 under 35 U.S.C. § 112, second paragraph, should be withdrawn.

-New Indefinite Rejections

Claims 81, 84, 85 and 89 stand rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicant regards as the invention.

Claims 81, 84, 85 and 89 are said to be indefinite because it is said to be unclear as to what "mild steel" and "tool steel" encompass.

With regard to "mild steel", enclosed is a copy of page 1-26 of Metals Handbook, Desk Edition, American Society For Metals, 1985, which defines "mild steel" as carbon steel with a maximum of about 0.25% C (for the definition of "carbon steel" see the enclosed copy of page 1-7 of the Metals Handbook).

With regard to "tool steel" enclosed is a copy of page 1-39 of the Metals Handbook, which defines "tool steel" as any of a class of carbon and alloy steels used to make tools. This definition goes on to say that tool steels are characterized by high hardness and resistance to abrasion, often accompanied by high toughness and resistance to softening at elevated temperature, and that these attributes are generally attained with high carbon and alloy steels. Also enclosed is page 18-1 of the Metals Handbook, which includes a discussion of tool steel.

It is submitted that in view of the above, the use of the terms "mild steel" and "tool steel" is sufficiently clear in the context used, and that this rejection should be withdrawn

### **§103 Rejections**

Claims 2-12, 16-19, 20-28, 30-35, 41, 44-52 and 75-80 stand rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Pat. No. 5,981,415 (Waku et al.) (the rejection of claims 5-8, 20, 26, and 32 being a new rejection). Claims 53-74 and 81-89 stand rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Pat. No. 5,981,415 (Waku et al.) in view of U.S. Pat. No. 4,035,162 (Brothers et al.).

The rejections of claims 2-12, 16-19, 20-28, 30-35, 41, 44-52 and 75-80 under 35 U.S.C. §103 as being unpatentable over '415 (Waku et al.), and claims 53-74 and 81-89 over '415 (Waku et al.) in view of '162 (Brothers et al.), should be withdrawn.

In one aspect, Applicant claims, in claim 41, a plurality of abrasive particles having a specified nominal grade, the plurality of abrasive particles having a particle size distribution ranging from fine to coarse, wherein at least a portion of the abrasive particles is a plurality of fused, crystalline abrasive particles, the fused abrasive particles comprising at least 20 percent by volume, based on the total metal oxide volume of the respective particle, eutectic material, wherein the eutectic material comprises eutectic of at least:

- (a) crystalline  $ZrO_2$  and
- (b) at least two of:
  - (i) crystalline  $Al_2O_3$ ,
  - (ii) first crystalline complex  $Al_2O_3 \cdot Y_2O_3$ , or
  - (iii) second, different, crystalline complex  $Al_2O_3 \cdot Y_2O_3$ .

In another aspect, Applicant claims, in claim 46, a method for making fused, crystalline abrasive particles comprising at least 20 percent by volume, based on the total volume of the respective particle, eutectic material, wherein the eutectic material comprises eutectic of at least (a) crystalline  $ZrO_2$  and (b) at least two of (i) crystalline  $Al_2O_3$ , (ii) first crystalline complex  $Al_2O_3 \cdot Y_2O_3$ , or (iii) second, different, crystalline complex  $Al_2O_3 \cdot Y_2O_3$ , the method comprising:

- melting at least one  $Al_2O_3$  source, at least one  $Y_2O_3$  source, and at least one  $ZrO_2$  source to provide a melt;
- converting the melt to the fused, crystalline abrasive particles; and

9

grading the fused, crystalline abrasive particles to provide plurality of abrasive particles having a specified nominal grade, the plurality of abrasive particle having a particle size distribution ranging from fine to coarse, wherein at least a portion of the abrasive particles is a plurality of the fused, crystalline abrasive particles.

In another aspect, Applicant claims, in claim 53, an abrasive article comprising a binder and a plurality of abrasive particles, wherein at least a portion of the abrasive particles are fused, crystalline abrasive particles comprising at least 20 percent by volume, based on the total volume of the respective particle, eutectic material, wherein the eutectic material comprises eutectic of at least:

- (a) crystalline  $ZrO_2$  and
- (b) at least two of:
  - (i) crystalline  $Al_2O_3$ ,
  - (ii) first crystalline complex  $Al_2O_3 \cdot Y_2O_3$ , or
  - (iii) second, different, crystalline complex  $Al_2O_3 \cdot Y_2O_3$ .

In another aspect, Applicant claims, in claim 61, a vitrified bonded abrasive article comprising a plurality of abrasive particles bonded together via vitrified bonding material, wherein at least a portion of the plurality of abrasive particles are fused, crystalline abrasive particles comprising at least 20 percent by volume, based on the total volume of the respective particle, eutectic material, wherein the eutectic material comprises eutectic of at least:

- (a) crystalline  $ZrO_2$  and
- (b) at least two of:
  - (i) crystalline  $Al_2O_3$ ,
  - (ii) first crystalline complex  $Al_2O_3 \cdot Y_2O_3$ , or
  - (iii) second, different, crystalline complex  $Al_2O_3 \cdot Y_2O_3$ .

In another aspect, Applicant claims, in claim 69, a method of abrading a surface, the method comprising:

providing an abrasive article comprising a binder and a plurality of abrasive particles, wherein at least a portion of the abrasive particles are fused, crystalline abrasive particle comprising at least 20 percent by volume, based on the total volume of the respective particle, eutectic material, wherein the eutectic material comprises eutectic of at least (a) crystalline  $ZrO_2$  and (b) at least two of (i) crystalline  $Al_2O_3$ , (ii) first crystalline complex  $Al_2O_3 \cdot Y_2O_3$ , or (iii) second, different, crystalline complex  $Al_2O_3 \cdot Y_2O_3$ ;

contacting at least one of the fused, crystalline abrasive particles with a surface of a workpiece; and

moving at least one of the contacted fused abrasive particle or the surface relative to the other to abrade at least a portion of the surface with the contacted fused abrasive particle.

In another aspect, Applicant claims, in claim 44, a plurality of abrasive particles having a specified nominal grade, the plurality of abrasive particle having a particle size distribution ranging from fine to coarse, wherein at least a portion of the abrasive particles is a plurality of fused, crystalline abrasive particles, the fused abrasive particles comprising at least 20 percent by volume, based on the total metal oxide volume of the respective particle, eutectic material, wherein the eutectic material comprises eutectic of at least:

- (a) crystalline complex  $\text{Al}_2\text{O}_3 \cdot \text{Y}_2\text{O}_3$  and
- (b) crystalline  $\text{ZrO}_2$ .

In another aspect, Applicant claims, in claim 52, a method for making fused, crystalline abrasive particles comprising at least 20 percent by volume, based on the total volume of the respective particle, eutectic material, wherein the eutectic material comprises eutectic of at least (a) crystalline complex  $\text{Al}_2\text{O}_3 \cdot \text{Y}_2\text{O}_3$  and (b) crystalline  $\text{ZrO}_2$ , the method comprising:

melting at least one  $\text{Al}_2\text{O}_3$  source, at least one  $\text{Y}_2\text{O}_3$  source, and at least one  $\text{ZrO}_2$  source to provide a melt;

converting the melt to the fused, crystalline abrasive particles; and

grading the fused, crystalline abrasive particles to provide plurality of abrasive particles having a specified nominal grade, the plurality of abrasive particle having a particle size distribution ranging from fine to coarse, wherein at least a portion of the abrasive particles is a plurality of the fused, crystalline abrasive particles.

In another aspect, Applicant claims, in claim 59, an abrasive article comprising a binder and a plurality of abrasive particles, wherein at least a portion of the abrasive particles are fused, crystalline abrasive particles comprising at least 20 percent by volume, based on the total volume of the respective particle, eutectic material, wherein the eutectic material comprises eutectic of at least:

- (a) crystalline complex  $\text{Al}_2\text{O}_3 \cdot \text{Y}_2\text{O}_3$  and
- (b) crystalline  $\text{ZrO}_2$ .

9

In another aspect, Applicant claims, in claim 67, a vitrified bonded abrasive article comprising a plurality of abrasive particles bonded together via vitrified bonding material, wherein at least a portion of the plurality of abrasive particles are fused, crystalline abrasive particles comprising at least 20 percent by volume, based on the total volume of the respective particle, eutectic material, wherein the eutectic material comprises eutectic of at least:

- (a) crystalline complex  $\text{Al}_2\text{O}_3 \cdot \text{Y}_2\text{O}_3$  and
- (b) crystalline  $\text{ZrO}_2$ .

In another aspect, Applicant claims, in claim 72, a method of abrading a surface, the method comprising:

providing an abrasive article comprising a binder and a plurality of abrasive particles, wherein at least a portion of the abrasive particles are fused, crystalline abrasive particle comprising at least 20 percent by volume, based on the total volume of the respective particle, eutectic material, wherein the eutectic material comprises eutectic of at least (a) crystalline complex  $\text{Al}_2\text{O}_3 \cdot \text{Y}_2\text{O}_3$  and (b) crystalline  $\text{ZrO}_2$ ;

contacting at least one of the fused, crystalline abrasive particles with a surface of a workpiece; and

moving at least one of the contacted fused abrasive particle or the surface relative to the other to abrade at least a portion of the surface with the contacted fused abrasive particle.

U.S. Pat. No. 5,981,415 (Waku et al.) reports a ceramic composite material consisting of two or more crystal phases of different components, each crystal phase having non-regular shape, the shape crystal phases having three dimensional continuous structures intertwined with other, at least one crystal phase thereof being a single crystal. The two or more crystal phases of different components constituting the ceramic material may be those of a combination of a eutectic system. It is said the metal oxides include aluminum oxide ( $\text{Al}_2\text{O}_3$ ), zirconium oxide ( $\text{ZrO}_2$ ), magnesium oxide ( $\text{MgO}$ ), silicon oxide ( $\text{SiO}_2$ ), titanium oxide ( $\text{TiO}_2$ ), barium oxide ( $\text{BaO}$ ), beryllium oxide ( $\text{BeO}$ ), calcium oxide ( $\text{CaO}$ ), chromium oxide ( $\text{Cr}_2\text{O}_3$ ), and rare earth oxides such as  $\text{La}_2\text{O}_3$ ,  $\text{Y}_2\text{O}_3$ ,  $\text{CeO}_2$ ,  $\text{Pr}_6\text{O}_{11}$ ,  $\text{Nd}_2\text{O}_3$ ,  $\text{Sm}_2\text{O}_3$ ,  $\text{Gd}_2\text{O}_3$ ,  $\text{Eu}_2\text{O}_3$ ,  $\text{Tb}_4\text{O}_7$ ,  $\text{Dy}_2\text{O}_3$ ,  $\text{Ho}_2\text{O}_3$ ,  $\text{Er}_2\text{O}_3$ ,  $\text{Tm}_2\text{O}_3$ ,  $\text{Yb}_2\text{O}_3$ , and  $\text{Lu}_2\text{O}_3$ . The complex oxides are said to include  $\text{LaAlO}_3$ ,  $\text{CeAlO}_3$ ,  $\text{PrAlO}_3$ ,  $\text{NdAlO}_3$ ,  $\text{SmAlO}_3$ ,  $\text{EuAlO}_3$ ,  $\text{GdAlO}_3$ ,  $\text{DyAlO}_3$ ,  $\text{ErAlO}_3$ ,  $\text{Yb}_4\text{AlO}_9$ ,  $\text{Er}_3\text{Al}_5\text{O}_{12}$ ,  $11\text{Al}_2\text{O}_3 \cdot \text{La}_2\text{O}_3$ ,  $11\text{Al}_2\text{O}_3 \cdot \text{Nd}_2\text{O}_3$ ,  $3\text{Dy}_2\text{O}_3 \cdot \text{Al}_2\text{O}_3$ ,  $2\text{Dy}_2\text{O}_3 \cdot \text{Al}_2\text{O}_3$ ,  $11\text{Al}_2\text{O}_3 \cdot \text{Pr}_2\text{O}_3$ ,  $\text{EuAl}_{11}\text{O}_{18}$ ,  $2\text{Gd}_2\text{O}_3 \cdot \text{Al}_2\text{O}_3$ ,  $11\text{Al}_2\text{O}_3 \cdot \text{Sm}_2\text{O}_3$ ,  $\text{Yb}_3\text{Al}_5\text{O}_3$ ,

9

$\text{CeAl}_{11}\text{O}_{18}$ , and  $\text{Er}_2\text{Al}_2\text{O}_9$ . In one alternative method, the melt is once solidified and pulverized and the pulverized material be then set in a crucible and subjected to unidirectional solidification.

It is stated in the Office that with respect to the rejection of claims 2-4, 9-12, 16-19, 21-25, 27, 28, 30, 31, 33-35, 41, 44-52, and 75-80 that Applicant argues that Waku et al. fails to teach a fused abrasive which contains the claimed specific tertiary eutectic and claimed specific binary eutectic. The Examiner disagrees with this argument because the reference is said to clearly teach eutectics which fall within the claimed tertiary and binary eutectic compositions. The reference is also said to teach at least two phases in the eutectic which reads on a tertiary eutectic. The reference is also said to define various phases that can be present, thus the various phases defined in combination with "two or more phases in the eutectic" read on the claimed eutectics. Since Applicant is said to have not argued the claimed eutectic composition in detail, no further comment on this is necessary. In addition, Applicant is said to state it is not clear that the result of the reference would be a eutectic. This is said to not be persuasive because in column 5, lines 18-20 the reference states that the combination is a eutectic system.

Although not agreeing that '415 (Waku et al.) teaches or properly suggests the eutectics required in Applicant's claims, even if it did, '415 fails to or suggest other features of the claims such as the "specified nominal grade" requirement, which is discussed below.

In addition, Applicant is said to appear to argue that this reference does not teach the "specified nominal grade" as required by the instant claims. The Examiner disagrees with this argument because the reference is said to state that the material is crushed and it is the Examiner's position that this crushed material will have a size which either falls in the category of coarse or fine, which is Applicant's definition of specified nominal grade.

In response, it is submitted that the meaning attributed to the term "specified nominal grade" above is incorrect. "Specified nominal grade" is defined on page 20, lines 20-31, bridging paragraph, page 21, lines 1-7 as industry (i.e., abrasive industry) accepted grading standards such as American National Standards Institute, Inc. (ANSI) standards, Federation of European Producers of Abrasive Products (FEPA) standards, and Japanese Industrial Standard (JIS) standards. It is well understood by one of ordinary skill in the abrasive art that such standards require more than just a particle size distribution from fine to coarse, and that the particular distribution is dictated by the standard for a given nominal grade.



USPN: 09/618,876

Docket No.: 35763US002

Further, it is stated in the Office Action that the desired particle size is a function of the application and mere recitation of that size does not represent a patentable distinction over this reference to one of ordinary skill in the art, lacking evidence to the contrary.

In response, it is submitted that by requiring a specified nominal grade, the specified abrasive particles must be in a specific form (i.e., part of a plurality of particles in grade). It is submitted that requiring the particles to be in such a specific form is a limitation that must be considered in evaluating the patentability of the claims. It is submitted that the Office Action does not provide a proper teaching or suggestion, for example, of the specified nominal grade requirement set forth in Applicant's claims.

Further, it is stated in the Office Action that Applicant apparently argues the "abrasive particle" limitation, as defined in the previous office action (i.e., Waku et al. teaches that fused materials based on alumina and yttria are known to be used as abrasive materials, thus making the use of the fused material according to the primary reference obvious as an abrasive material), as not being obvious, yet fail to define reasons supporting this position. It is also stated in the Office Action that clearly one skilled in the art from reading column 2, line 54 and the paragraph bridging columns 8-9 of Waku would find the use of the material according to the EP\* reference obvious as an abrasive. Applicant is said to state that this obviousness rejection is based on improper hindsight. The Examiner disagrees with this argument because it is said one skilled in the art would have known the applications of alumina/oxide composites includes abrasive applications, as defined in Waku.

As discussed above, "specified nominal grade" is defined on page 20, lines 20-31, bridging paragraph, page 21, lines 1-7 as industry (i.e., abrasive industry) accepted grading standards, and requiring the abrasive particles to be in such a specific form is a limitation that must be considered in evaluating the patentability of the claims, although since '415 (Waku et al.) fails to teach the cutectics required in Applicant's claims, reliance on the specified nominal grade requirement is not even necessary to distinguish the invention from '415.

Although it is stated in the Office Action that "[c]learly one skilled in the art from reading column 2, line 54 and the paragraph bridging columns 8-9 of Waku would find the use of the material obvious as an abrasive" and that "... one skilled in the art would have known the applications of alumina/oxide composites includes abrasive applications, as defined in Waku", it is submitted that column 2, line 54 and the paragraph bridging columns 8-9 of '415 (Waku et al.) fail to properly support such conclusions.

\* The current rejections do not rely on EP\* document.

11

USPN: 09/618,876

Docket No.: 35763US002

The sentence corresponding to col. 2, line 54, which is in the "Background of the Invention" section, reads "For example,  $Al_2O_3$ , is chemically stable and hard and has a relatively high strength and an excellent electrical insulation, and therefore it is widely used in various applications including insulating materials, abrasives, cutting tool materials, IC circuit boards, laser emitting materials, catalyst carriers, and biomaterials." The paragraph bridging at columns 8-9 of '415 (Waku et al.) reads:

Also, the ceramic composite material of the present invention may be useful in many applications in which oxide ceramics such as  $Al_2O_3$  are in practice used. Such applications include high temperature materials such as heat exchange members, fusion furnace materials, nuclear furnace materials and fuel cell materials; abrasion resistant members, cutting tool members, corrosion resistant materials, superconducting members, magnetic refrigeration materials, insulating members, phosphor materials, X-ray sensitizers, laser emitting elements, dielectric elements, positive temperature coefficient materials (PTC), condensers, varistors and other electronic devices, optical lenses, catalyst carriers, and many other applications.

It is worth noting that this list of uses of the '415 (Waku et al.) ceramic composite material (in paragraph bridging at columns 8-9) is significantly longer than the list of uses of  $Al_2O_3$  in col. 2, and that some of the listed applications are the same. Although "abrasives" is listed in col. 2 as a use of  $Al_2O_3$ , it is not listed in the much longer list of uses in the bridging paragraph at col. 8-9 for the '415 (Waku et al.) ceramic composite material. If it was intended to teach or suggest the '415 (Waku et al.) ceramic composite material for use as an abrasive, it is puzzling why it was not listed with the other relatively long list of uses at col. 8-9. Moreover, even if it were known that known abrasives include alumina/oxide composites, it would not necessarily mean that all alumina/oxide composites are suitable for use as abrasives.

Hence, it is submitted that to reach the conclusion that '415 (Waku et al.) teaches or suggests using the '415 ceramic composite material as abrasive particles in a specified nominal grade as required in Applicant's claims 41, 44, 46, and 52 requires an impermissible, strained reading of '415 that effectively includes the improper use of hindsight analysis.

U.S. Pat. No. 5,981,415 (Waku et al.) in view of U.S. Pat. No. 4,035,162 (Brothers et al.)

12

9

It is stated in the Office Action that Applicant fails to argue the combination of '415 (Waku et al.) in view of '162 (Brothers et al.).

Applicants respectfully disagree with this statement, however to facilitate prosecution, further clarification of the argument is provided below.

'162 (Brothers et al.) is relied upon to show that fused abrasive grains are known to be used as abrasives in the manufacture of bonded abrasives and coated abrasives.

Claims 53 and 61 are directed toward abrasive articles comprising fused abrasive particles comprising at least 20 percent by volume, based on the total metal oxide volume of the respective particle, eutectic material, wherein the eutectic material comprises eutectic of at least:

(a) crystalline  $ZrO_2$  and

(b) at least two of:

(i) crystalline  $Al_2O_3$ ,

(ii) first crystalline complex  $Al_2O_3 \cdot Y_2O_3$ , or

(iii) second, different, crystalline complex  $Al_2O_3 \cdot Y_2O_3$ .

Claim 69 is directed toward abrading a surface with an abrasive article comprising fused abrasive particles comprising at least 20 percent by volume, based on the total metal oxide volume of the respective particle, eutectic material, wherein the eutectic material comprises eutectic of at least:

(a) crystalline  $ZrO_2$  and

(b) at least two of:

(i) crystalline  $Al_2O_3$ ,

(ii) first crystalline complex  $Al_2O_3 \cdot Y_2O_3$ , or

(iii) second, different, crystalline complex  $Al_2O_3 \cdot Y_2O_3$ ,

wherein at least one of such fused, crystalline abrasive particles abrades the surface.

Claims 59 and 67 are directed toward abrasive articles comprising fused, crystalline abrasive particles comprising at least 20 percent by volume, based on the total metal oxide volume of the respective particle, eutectic material, wherein the eutectic material comprises eutectic of at least (a) crystalline complex  $Al_2O_3 \cdot Y_2O_3$  and (b) crystalline  $ZrO_2$ .

Claim 72 is directed toward abrading a surface with an abrasive article comprising fused, crystalline abrasive particles comprising at least 20 percent by volume, based on the total metal oxide volume of the respective particle, eutectic material, wherein the eutectic material comprises eutectic of at least:

(a) crystalline complex  $\text{Al}_2\text{O}_3\cdot\text{Y}_2\text{O}_3$  and

(b) crystalline  $\text{ZrO}_2$ ,

wherein at least one of such fused, crystalline abrasive particles abrades the surface.

As discussed above, '415 (Waku et al.) fails to teach or properly suggest use of the materials reported therein as abrasives. It follows that if '415 fails to teach or properly suggest use of such materials as abrasives, then '415 also fails to teach or properly suggest use of such materials as abrasives in abrasive articles.

As there is no teaching or proper suggestion in '415 (Waku et al.) of the '415 materials as abrasives, it is unclear, for example, why one of ordinary skill in the art would be motivated, absent the inappropriate use of hindsight analysis, to select '162 (Brothers et al.) to try to provide the inventions claimed in claims 53, 59, 61, 67, 69, and 72.

Further, with respect to the new rejection of claims 5-8, 20, 26, and 32 it is stated in the Office action that after further review of the reference and since Waku et al. states the "material may have a uniform structure which does not include colonies, it is the Examiner's position that the term may in this statement does not positively exclude colonies from being present, thus said colonies are within the scope of the reference. In view of colonies being present, the limitations of the above claims are met because colonies must have a size and the broad interpretation of the colonies having the claimed size in the absence of any critical evidence showing the contrary.

While not agreeing that the statements in the Office Action with respect to the rejection to claims 5-8, 20, 26, and 32 are correct, it is submitted that since claims 5-8, 20, 26, and 32 depend directly or indirectly from one of the independent claims discussed above, and since the independent claims are patentable, for example, for the reasons given above, claim 5-8, 20, 26, and 32 should also be patentable regardless of whether or not such statements are correct or not.

Claims 2, 17 and 75-76 add additional limitations to claim 41. Claim 41 is patentable for the reasons given above. Thus, claims 2, 17 and 75-76 should also be patentable.

Claims 3, 16 and 23 add additional limitations to claim 2. Claim 2 is patentable for the reasons given above. Thus, claims 3, 16 and 23 should also be patentable.

Claims 4-5, 7, and 9-11 add additional limitations to claim 3. Claim 3 is patentable for the reasons given above. Thus, claims 4-5, 7, and 9-11 should also be patentable.

Claim 6 adds an additional limitation to claim 5. Claim 5 is patentable for the reasons given above. Thus, claim 6 should also be patentable.

Claim 8 adds an additional limitation to claim 7. Claim 7 is patentable for the reasons given above. Thus, claim 8 should also be patentable.

Claim 18 adds an additional limitation to claim 17. Claim 17 is patentable for the reasons given above. Thus, claim 18 should also be patentable.

Claim 19 adds an additional limitation to claim 18. Claim 18 is patentable for the reasons given above. Thus, claim 19 should also be patentable.

Claims 20-22 add additional limitations to claim 19. Claim 19 is patentable for the reasons given above. Thus, claims 20-22 should also be patentable.

Claim 24 adds an additional limitation to claim 23. Claim 23 is patentable for the reasons given above. Thus, claim 24 should also be patentable.

Claim 25 adds an additional limitation to claim 24. Claim 24 is patentable for the reasons given above. Thus, claim 25 should also be patentable.

Claims 26-28 add additional limitations to claim 25. Claim 25 is patentable for the reasons given above. Thus, claims 26-28 should also be patentable.

Claim 30 adds an additional limitation to claim 44. Claim 44 is patentable for the reasons given above. Thus, claim 30 should also be patentable.

Claims 31-35 add additional limitations to claim 30. Claim 30 is patentable for the reasons given above. Thus, claims 31-35 should also be patentable.

Claims 45 and 78-80 add additional limitations to claim 44. Claim 44 is patentable for the reasons given above. Thus, claim 45 and 78-80 should also be patentable.

Claim 47 adds an additional limitation to claim 46. Claim 46 is patentable for the reasons given above. Thus, claim 47 should also be patentable.

Claims 48-49 add additional limitations to claim 47. Claim 47 is patentable for the reasons given above. Thus, claims 48-49 should also be patentable.

Claims 50-51 add additional limitations to claim 46. Claim 46 is patentable for the reasons given above. Thus, claims 50-51 should also be patentable.

Claims 54-58 add additional limitations to claim 53. Claim 53 is patentable for the reasons given above. Thus, claims 54-58 should also be patentable.

Claim 60 adds an additional limitation to claim 59. Claim 59 is patentable for the reasons given above. Thus, claim 60 should also be patentable.

9

Claims 62-66 add additional limitations to claim 61. Claim 61 is patentable for the reasons given above. Thus, claims 62-66 should also be patentable.

Claim 68 adds an additional limitation to claim 67. Claim 67 is patentable for the reasons given above. Thus, claim 68 should also be patentable.

Claims 70 and 71 add additional limitations to claim 69. Claim 69 is patentable for the reasons given above. Thus, claims 70 and 71 should also be patentable.

Claims 73-74 and 89 add additional limitations to claim 72. Claim 72 is patentable for the reasons given above. Thus, claims 73-74 and 89 should also be patentable.

Claims 81-88 add additional limitations to claim 69. Claim 69 is patentable for the reasons given above. Thus, claims 81-88 should also be patentable.

In summary, the rejections of claims 2-12, 16-19, 20-28, 30-35, 41, 44-52 and 75-80 under 35 U.S.C. §103 as being unpatentable over '415 (Waku et al.), and claims 53-74 and 81-89 over '415 (Waku et al.) in view of '162 (Brothers et al.), should be withdrawn.

#### Allowable Subject Matter

Claims 13-15 are object to as being dependent on a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Claims 13-15 have each been rewritten in independent form as suggested by the Examiner.

In view of the above, it is submitted that the application is in condition for allowance. Reconsideration of the rejection is requested. Allowance of claims 2-28, 30-35, 41 and 44-89, as amended, at an early date is solicited.

Registration Number 35,048	Telephone Number 651-736-0641
Date <i>June 7, 2002</i>	

Respectfully submitted,

By

*[Signature]*  
Gregory D. Allen

Office of Intellectual Property Counsel  
3M Innovative Properties Company  
P.O. Box 33427  
St. Paul, Minnesota 55133-3427  
Facsimile: (651) 736-3833

p:\allengrel\app\035000\35763\55763-01\55763 002 m2.doc

9

**Version With Markings to Show Changes Made****In The Specification**

On page 41, please amend the following paragraph starting on line 13 and ending on line 22:

FIG. 9 is a scanning electron microscope (SEM) photomicrograph of a polished section (prepared as described in Comparative Example A) of fused Comparative Example F material. The photomicrograph shows a eutectic-derived microstructure comprising a plurality of colonies. The colonies are about 10-40 micrometers in size. Based on powder x-ray diffraction of a portion of Comparative Example E material, and examination of the polished sample using SEM in the backscattered mode, it is believed that the white portions in the photomicrograph were crystalline  $Y_3Al_5O_{12}$ , and the dark portions a crystalline  $Al_2O_3$ -rich spinel solid solution phase. The width of these phases observed in the polished section were up to about 1 micrometer [2 micrometers].

**In The Claims**

Please amend claims 13-15 as follows:

13. A plurality of abrasive particles having a specified nominal grade, said plurality of abrasive particle having a particle size distribution ranging from fine to coarse, wherein at least a portion of said abrasive particles is a plurality of fused, crystalline abrasive particles, said fused abrasive particles comprising at least 20 percent by volume, based on the total metal oxide volume of the respective particle, eutectic material, wherein said eutectic material comprises eutectic of at least:

(a) crystalline  $ZrO_2$  and

(b) at least two of:

(i) crystalline  $Al_2O_3$ ,

(ii) first crystalline complex  $Al_2O_3 \cdot Y_2O_3$ , or

(iii) second, different, crystalline complex  $Al_2O_3 \cdot Y_2O_3$ , wherein said fused, crystalline abrasive particles comprise at least 50 percent by volume, based on the total metal oxide volume of the respective particle, of said eutectic material, wherein the abrasive particles comprising, on a theoretical oxide basis, at least 40 percent by weight  $Al_2O_3$ , based on the total metal oxide content of the respective particle, and [The plurality of abrasive particles according to claim 3,] wherein a portion of said complex  $Al_2O_3 \cdot Y_2O_3$  Al cations are

9

substituted with at least one cation selected from the following cations: Cr, Ti, Sc, Fe, Mg, Ca, Si, and Co.

14. A plurality of abrasive particles having a specified nominal grade, said plurality of abrasive particle having a particle size distribution ranging from fine to coarse, wherein at least a portion of said abrasive particles is a plurality of fused, crystalline abrasive particles, said fused abrasive particles comprising at least 20 percent by volume, based on the total metal oxide volume of the respective particle, eutectic material, wherein said eutectic material comprises eutectic of at least:

(a) crystalline  $ZrO_2$  and

(b) at least two of:

(i) crystalline  $Al_2O_3$ ,

(ii) first crystalline complex  $Al_2O_3 \cdot Y_2O_3$ , or

(iii) second, different, crystalline complex  $Al_2O_3 \cdot Y_2O_3$ , wherein said fused, crystalline abrasive particles comprise at least 50 percent by volume, based on the total metal oxide volume of the respective particle, of said eutectic material, wherein the abrasive particles comprising, on a theoretical oxide basis, at least 40 percent by weight  $Al_2O_3$ , based on the total metal oxide content of the respective particle, and [The plurality of abrasive particles according to claim 3,] wherein a portion of said complex  $Al_2O_3 \cdot Y_2O_3$  Y cations are substituted with at least one cation selected from the following cations: Ce, Dy, Er, Eu, Gd, Ho, La, Lu, Nd, Pr, Sm, Th, Tm, and Yb.

15. A plurality of abrasive particles having a specified nominal grade, said plurality of abrasive particle having a particle size distribution ranging from fine to coarse, wherein at least a portion of said abrasive particles is a plurality of fused, crystalline abrasive particles, said fused abrasive particles comprising at least 20 percent by volume, based on the total metal oxide volume of the respective particle, eutectic material, wherein said eutectic material comprises eutectic of at least:

(a) crystalline  $ZrO_2$  and

(b) at least two of:

(i) crystalline  $Al_2O_3$ ,

(ii) first crystalline complex  $Al_2O_3 \cdot Y_2O_3$ , or

9

(iii) second, different, crystalline complex  $\text{Al}_2\text{O}_3\cdot\text{Y}_2\text{O}_3$ , wherein said fused, crystalline abrasive particles comprise at least 50 percent by volume, based on the total metal oxide volume of the respective particle, of said eutectic material, wherein the abrasive particles comprising, on a theoretical oxide basis, at least 40 percent by weight  $\text{Al}_2\text{O}_3$ , based on the total metal oxide content of the respective particle, and [The plurality of abrasive particles according to claim 3,] wherein a portion of said complex  $\text{Al}_2\text{O}_3\cdot\text{Y}_2\text{O}_3$  Y cations are substituted with at least one cation selected from the following cations: Fe, Ti, Mn, V, Cr, Co, Ni, Cu, Mg, Ca, and Sr.

9



# Metals Handbook®

## Desk Edition



American Society for Metals

9

Copyright © 1985  
by the  
AMERICAN SOCIETY FOR METALS  
All rights reserved

First printing, November 1984

Second printing, May 1985

No part of this book may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the written permission of the copyright owner.

Metals Handbook is a collective effort involving thousands of technical specialists. It brings together in one book a wealth of information from world-wide sources to help scientists, engineers, and technicians solve current and long-range problems.

Great care is taken in the compilation and production of this volume, but it should be made clear that no warranties, express or implied, are given in connection with the accuracy or completeness of this publication, and no responsibility can be taken for any claims that may arise.

Nothing contained in the Metals Handbook shall be construed as a grant of any right of manufacture, sale, use, or reproduction, in connection with any method, process, apparatus, product, composition, or system, whether or not covered by letters patent, copyright, or trademark, and nothing contained in the Metals Handbook shall be construed as a defense against any alleged infringement of letters patent, copyright, or trademark, or as a defense against any liability for such infringement.

Comments, criticisms, and suggestions are invited, and should be forwarded to the American Society for Metals, Metals Park, Ohio 44073.

Library of Congress Catalog Card Number: 84-71465  
ISBN: 0-87170-18X-X  
SAN: 204-7586

Project Director: Timothy L. Gall  
ASM Staff Assistants: Joan L. Tomsic and Judith S. Gibbs  
Editorial and production coordination by Carnes Publication Services, Inc.  
President: William J. Carnes  
Project Manager: Craig W. Kirkpatrick

PRINTED IN THE UNITED STATES OF AMERICA

## 1-26 Glossary of Metallurgical Terms and Engineering Tables

vial to make reprecipitation profitable.  
 migration. Movement of entities (such as electrons, ions, atoms, molecules, vacancies and grain boundaries) from one place to another under the influence of a driving force (such as an electrical potential or a concentration gradient).

MIG welding. See metal inert-gas welding.  
 mil. One thousandth of an inch (0.001 in.).

mild steel. Carbon steel with a maximum of about 0.25% C.

mill. (1) A facility where metals are hot worked, cold worked, or melted and cast into standard shapes suitable for secondary fabrication into commercial products. (2) A production line, usually of four or more stands, for hot rolling metal into standard shapes such as bar, rod, plate, sheet or strip. (3) A single machine for hot rolling, cold rolling or extruding metal; examples include blooming mill, cluster mill, four-high mill, and Sendzimer mill. (4) A shop term for milling cutter. (5) A machine or group of machines for grinding or crushing ores and other minerals; see ball mill, milling. (2)

mill edge. The terminal edge produced in hot rolling. This edge is customarily removed when hot rolled sheets are further processed into cold rolled sheets.

Miller ladders. A system for identifying planes and directions in any crystal system by means of sets of integers. The indices of a plane are related to the intercepts of that plane with the axes of a unit cell; the indices of a direction, to the multiples of lattice parameter that represent the coordinates of a point on a line parallel to the direction and passing through the arbitrarily chosen origin of a unit cell.

mill finish. A nonstandard (and typically nonuniform) surface finish on mill products that are delivered without being subjected to a special surface treatment (other than a corrosion-preventive treatment) after the final working or heat treating step.

milling. (1) Removing metal with a milling cutter. (2) The mechanical treatment of material, as in a ball mill, to produce particles or alter their size or shape, or to combine one component of a powder mixture with another.

milling cutter. A rotary cutting tool provided with one or more cutting elements, called teeth, which intermittently engage the workpiece and remove material by relative movement of the workpiece and cutter.

mill product. Any commercial product of a mill.

mill scale. The heavy oxide layer formed during iron fabrication or heat treatment of steels.

mineral dressing. Physical and chemical concentration of raw ore into a product from which a metal can be recovered at a profit.

minimized spangle. A hot dip galvanized coating of very small grain size, which makes the spangle less visible when the part is subsequently painted.

minimum bend radius. The minimum radius over which a metal product can be bent to a given angle without fracture.

minus sieve. The portion of a sample of a granular substance (such as metal powder) that passes through a standard sieve of specified number. Contrast with plus sieve.

monobridged. A natural mixture of rare-earth elements (atomic numbers 57 through 71) in metallic form. It contains about 30% cerium, the remainder being principally lanthanum and neodymium.

misfit. Error in register between forged surfaces formed by opposing dies.

misrun. A casting not fully formed, resulting from the

metal solidifying before the mold is filled.

mixed dislocation. See dislocation.

milling. In powder metallurgy, the thorough intermingling of powders of two or more different materials (not blending).

mixing chamber. The part of a torch or furnace burner in which gases are mixed.

modification. Treatment of molten hypoeutectic (8 to 15% Si) or hypereutectic (13 to 19% Si) aluminum-silicon alloys to improve mechanical properties of the solid alloy by refinement of the size and distribution of the silicon phase. Involves additions of small percentages of sodium or strontium (hypoeutectic alloys) or of phosphorus (hypereutectic alloys).

modulus of elasticity. A measure of the rigidity of metal. Ratio of stress, below the proportional limit, in corresponding strain. Specifically, the modulus obtained in tension or compression is Young's modulus, shear modulus or modulus of extensibility; the modulus obtained in torsion or shear is modulus of rigidity; shear modulus or modulus of torsion, the modulus governing the ratio of the mean normal stress to the change in volume per unit volume is the bulk modulus. The tangent modulus and secant modulus are not accepted within the proportional limit; the latter is the slope of the stress-strain curve at a specified point, the latter is the slope of a line from the origin to a specified point on the stress-strain curve. Also called elastic modulus and coefficient of elasticity.

modulus of rigidity. See modulus of elasticity.

modulus of rupture. Nominal stress at fracture in a bend test or torsion test. In bending, modulus of rupture is the bending moment at fracture divided by the section modulus. In torsion, modulus of rupture is the torque at fracture divided by the polar section modulus.

modulus of strain hardening. See preferred term, rate of strain hardening.

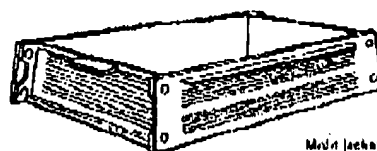
Mohs' scale. A scratch hardness test for determining comparative hardness using ten standard minerals from talc (the softest) to diamond (the hardest).

mold. (1) A form made of sand, metal or other material that contains the cavity into which molten metal is poured to produce a casting of definite shape and outline. (2) Same as die.

molding machine. A machine for making sand molds by mechanically compacting sand around a pattern.

molding press. A press used to form powder metal surge compacts.

mono jacket. Wood or metal form that is slipped over a sand mold for support during pouring.



Mold jacket

mold wash. An aqueous or alcoholic emulsion or suspension of various materials used to coat the surface of a mold cavity.

monel process. A process for extracting and purifying nickel. The main features consist of forming nickel cathodically by reaction of finely divided reduced metal with carbon monoxide, then decomposing the nickel cathodically, to deposit purified nickel on small nickel pellets.

monotectic. An isothermal reversible reaction in a binary system, in which a liquid on cooling decomposes into a second liquid of a different composition and a solid. It differs from a eutectic in that only one of the two products of the reaction is below its freezing range.

monotone hardness test. A method of determining the indentation hardness of a metal by measuring the load required to force a spherical penetrator into the metal to a specified depth. Now obsolete.

monotropism. The ability of a solid to exist in two or more forms (crystal structures), but in which one form is the stable modification at all temperatures and pressures. Ferrite and martensite are a monotropic pair below A<sub>1</sub>; in steels, for example. May also be spelled monotrophism.

mosaic structure. In crystals, a substructure in which neighboring regions have only slightly differing orientations.

M, temperature. For any alloy system, the temperature at which martensite starts to form on cooling. See transformation temperature for the definition applicable to ferrous alloys.

molding. Mixing sand and clay particles with water by kneading, rolling, rubbing or stirring.

multiaxial stresses. Any stress state in which two or three principal stresses are not zero.

multiple. A piece of stock cut from a longer mill product to provide the exact amount of material needed for a single workpiece.

multiple-impulse welding. Spot, projection or upset welding with more than one impulse of current during a single machine cycle. Sometimes called pulsation welding.

multiple-pass weld. A weld made by depositing successive layers of metal with two or more successive passes.

multiple-slide press. A press with individual slides, both into the main slide or connected to individual eccentric on the main shaft, that can be adjusted to give variations in length of stroke and in timing.

multiple spot welding. Spot welding in which several spots are made during one complete cycle of the welding machine.

## N

native metal. (1) Any deposit in the earth's crust consisting of uncombined metal. (2) The metal in such a deposit.

natural aging. Spontaneous aging of a supersaturated solid solution at room temperature. See aging, and compare with artificial aging.

natural strain. See strain.

necking. (1) Reducing the cross-sectional area of metal in a localized area by stretching. (2) Reducing the diameter of a portion of the length of a cylindrical shell or tube.

necking down. Localized reduction in area of a specimen during tensile deformation.

necking strain. Same as uniform strain.

negative rake. Describes a tooth face in rotation whose cutting edge lags the surface of the tooth face. See sketch accompanying face mill.

network structure. A structure in which one constituent occurs primarily at the grain boundaries, thus partially or completely enveloping the grains of the other constituents.

Neumann band. Mechanical twin in ferrite.

neutral flame. A gas flame in which there is an excess of either fuel or oxygen in the inner flame. Oxygen from ambient air is used to complete the combustion of CO<sub>2</sub> and H<sub>2</sub> produced in the inner flame.

neutron. Elementary nuclear particle that has a mass approximately the same as that of a hydrogen atom and that is electrically neutral; its mass is 1.008 665 mass units.

neutron embrittlement. Embrittlement resulting from bombardment with neutrons, usually encountered in metals that have been exposed to a neutron flux in the core of a reactor. In steels, neutron embrittlement is evidenced by a rise in the ductile-to-brittle transition temperature.

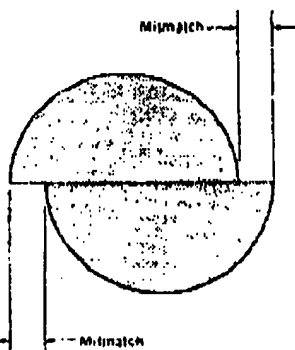
notching. Contour cutting of sheet metal by use of a rapidly reciprocating punch that makes numerous small cuts.

nitriding. Introducing nitrogen into the surface layer of a solid ferrous alloy by holding at a suitable temperature (below A<sub>1</sub>, for ferritic steels) in contact with a nitrogenous material, usually ammonia or molten cyanide of appropriate composition. Quenching is not required to produce a hard case.

nitrocarburizing. Any of several processes in which both nitrogen and carbon are absorbed into the surface layers of a ferrous material at temperatures below the lower critical temperature and, by diffusion, create a concentration gradient. Nitrocarburizing is done mainly to provide an annealing surface layer and to improve fatigue resistance. Compare with carbonitriding.

noble metal. (1) A metal whose potential is highly positive relative to the hydrogen electrode. (2) A metal with marked resistance to chemical reaction, particularly to oxidation and to solution by inorganic acids. The term is often used in synonymy with precious metal. Contrast with base metal (4).

noble potential. The potential for the passive state, in the metal can exist in both the active and passive states in a given medium.



**carbide** *carbide*. Compact into two or more portions by which the original shape of the punch faces and the punch itself are preserved.

**carbide**. A compound of carbon with one or more metallic elements.

**carbide tools**. Cutting or forming tools, usually made of tungsten, titanium, tantalum, or niobium carbide, or a combination of them, in a matrix of cobalt, nickel, or other metals. Carbide tools are characterized by high hardnesses and compressive strengths and may be coated to improve wear resistance.

**carbon dioxide welding**. Gas metal-arc welding using carbon dioxide as the shielding gas.

**carbon edges**. Carbonaceous deposits in a wavy pattern along the edges of a sheet or strip; also known as snake edges.

**carbon electrode**. A carbon or graphite rod used in carbon-arc equipment, such as in carbon-arc welding or cutting torches.

**carbon equivalent**. (1) For cast iron, an empirical relationship of the total carbon, silicon and phosphorus contents expressed by the formula:

$$CE = TC + \frac{1}{3}(Si + P)$$

(2) For rating of weldability:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

**carburizing**. A case hardening process in which a suitable ferrous material is heated above the lower transformation temperature in a gaseous atmosphere of such composition as to cause simultaneous absorption of carbon and nitrogen by the surface and, by diffusion, create a concentration gradient. The process is completed by cooling at a rate that produces the desired properties in the workpiece.

**carburization**. Conversion of an organic substance into elemental carbon. (Should not be confused with carburizing.)

**carbon potential**. A measure of the ability of an environment containing active carbon to alter or maintain, under prescribed conditions, the carbon level of the steel. NUPP. In any particular environment, the carbon level attained will depend on such factors as temperature, time and steel composition.

**carbon restoration**. Replacing the carbon lost in the surface layer from previous processing by carburizing this layer to substantially the original carbon level. Sometimes called recarburizing.

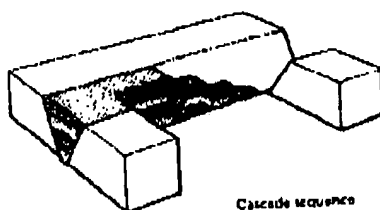
**carbon steel**. Steel having no specified minimum quantity for any alloying element (other than the commonly accepted amounts of manganese, silicon and copper) and containing only an incidental amount of any element other than carbon, silicon, manganese, copper, sulfur and phosphorus.

**carbonyl powder**. A metal powder prepared by the thermal decomposition of a metal carbonyl.

**carburizing**. Absorption and diffusion of carbon into solid ferrous alloys by heating, to a temperature usually above  $A_{c1}$ , in contact with a suitable carbonaceous material. A form of *case hardening* that produces a carbon gradient extending inward from the surface, enabling the surface layer to be hardened either by quenching directly from the carburizing temperature or by cooling to room temperature, then rehardening and quenching.

**carburizing flame**. A gas flame that will introduce carbon into some heated metals, as during a gas welding operation. A carburizing flame is a *reducing flame*, but a reducing flame is not necessarily a carburizing flame.

**cascade sequence**. A welding sequence in which a continuous multiple pass weld is built up by depositing weld beads in overlapping layers, usually laid in a backstep sequence. Compare with *block sequence*.



Cascade sequence

**case**. That portion of a ferrous alloy, extending inward from the surface, whose composition has been altered.

**case**. That portion of the alloy (a) whose composition has been measurably altered from the original composition, (b) that appears dark on an etched cross section, or (c) that has a hardness, after hardening, equal to or greater than a specified value. Contrast with *core* (2).

**case hardening**. A generic term covering several processes applicable to steel that change the chemical composition of the surface layer by absorption of carbon, nitrogen, or a mixture of the two and, by diffusion, create a concentration gradient. The processes commonly used are *carburizing* and *quench hardening*, *cyaniding*, *nitriding*, and *carburizing*. The use of the applicable specific process name is preferred.

**caseholder**. A lightweight holder, used to contain radiographic films during exposure to x-rays or gamma rays, that may or may not contain intensifying or filter screens, or both. A distinction is often made between a *case*, which has positive means for ensuring contact between screens and film and is usually rigid, and an *exposure holder*, which is rather flexible.

**CASS test**. Abbreviation for *copper-accelerated salt-spray test*.

**cast**. See *die proof*.

**cast-alloy tool**. A cutting tool made by casting a suitable alloy and used at machining speeds between those for high speed steels and sintered carbides.

**casting**. (1) An object in or near finished shape obtained by solidification of a substance in a mold. (2) Pouring molten metal into a mold to produce an object of desired shape.

**casting copper**. Fire-refined tough pitch copper usually cast from melted secondary metal into ingot bars only, and used for making foundry castings but not wrought products.

**casting shrinkage**. (1) Liquid shrinkage—the reduction in volume of liquid metal as it cools to the liquidus. (2) Solidification shrinkage—the reduction in volume of metal from beginning to end of solidification. (3) Solid shrinkage—the reduction in volume of metal from the solidus to room temperature.

**casting strains**. Strains in a casting caused by casting stresses that develop as the casting cools.

**casting stresses**. Residual stresses set up when the shape of a casting impedes contraction of the solidified casting during cooling.

**cast iron**. A generic term for a large family of cast ferrous alloys in which the carbon content exceeds the solubility of carbon in austenite at the eutectic temperature. Most cast irons contain at least 2% carbon, plus silicon and sulfur, and may or may not contain other alloying elements. For the various forms: *gray cast iron*, *white cast iron*, *malleable cast iron* and *ductile cast iron*, the word "cast" is often left out, resulting in "gray iron," "white iron," "malleable iron" and "ductile iron," respectively.

**cast steel**. Steel in the form of castings.

**cast structure**. The metallographic structure of a casting evidenced by shape and orientation of grains and by segregation of impurities.

**catalyst**. A substance capable of changing the rate of a reaction without itself undergoing any net change.

**cathodic failure**. Sudden failure of a component or assembly that frequently results in extensive secondary damage to adjacent components or assemblies.

**cathode**. The electrode where electrons enter an operating system such as a battery, an electrolytic cell, an x-ray tube or a vacuum tube. In the first of these, it is positive; in the other three, negative. In a battery or electrolytic cell, it is the electrode where reduction occurs. Contrast with *anode*.

**cathode compartment**. In an electrolytic cell, the enclosure formed by a diaphragm around the cathode.

**cathode copper**. Copper deposited at the cathode in electrolytic refining.

**cathode efficiency**. Current efficiency at the cathode.

**cathode film**. The portion of solution in immediate contact with the cathode during electrolysis.

**cathodic cleaning**. Electrolytic cleaning in which the work is the cathode.

**cathodic pickling**. Electrolytic pickling in which the work is the cathode.

**cathodic protection**. Partial or complete protection of a metal from corrosion by making it a cathode, using either a galvanic or an impressed current. Contrast with *anodic protection*.

**catholyte**. The electrolyte adjacent to the cathode in an electrolytic cell; in a divided cell, the portion on the cathode side of the diaphragm.

**cathode**. A positively charged ion; it flows in the cathode in electrolysis.

**cathodic detergent**. A detergent in which the cathode is the active part.

**cathodic cracking**. A form of stress corrosion cracking most frequently encountered in carbon steels or iron-chromium-nickel alloys that are exposed to concentrated hydroxide solutions at temperatures of 200 to 250 °C (400 to 480 °F).

**cathodic dip**. A strongly alkaline solution into which metal is immersed for etching, for neutralizing acid or for removing organic materials such as greases or paints.

**cavitation**. The formation and instantaneous collapse of innumerable tiny voids or cavities within a liquid subjected to rapid and intense pressure changes.

**cavitation produced by ultrasonic radiation** is sometimes used to effect violent localized agitation. Cavitation caused by severe turbulent flow often leads to *cavitation damage*.

**cavitation damage**. Erosion of a solid surface through the formation and collapse of cavities in an adjacent liquid.

**cavitation erosion**. See preferred term, *cavitation damage*.

**cell feed**. The material supplied to the cell in the electrolytic production of metals.

**cementation**. Introduction of one or more elements into the outer portion of a metal object by means of diffusion at high temperature.

**cement copper**. Impure copper recovered by chemical deposition when iron (most often shredded steel scrap) is brought into prolonged contact with a dilute copper sulfate solution.

**cermet carbide**. A solid and coherent mass made by pressing and sintering a mixture of powders of one or more metallic carbides and a much smaller amount of a metal, such as cobalt, to serve as a binder.

**cementite**. A compound of iron and carbon, known chemically as iron carbide and having the approximate chemical formula  $Fe_3C$ . It is characterized by an orthorhombic crystal structure. When it occurs as a phase in steel, the chemical composition will be altered by the presence of manganese and other carbide-forming elements.

**center drilling**. Drilling a short, conical hole in the end of a workpiece—a hole to be used to center the workpiece for turning on a lathe.

**centering plug**. A plug fitting both spindle and cutter to ensure concentricity of the center mounting.

**centerless grinding**. Grinding the outside or inside of a workpiece mounted on rollers rather than on centers. The workpiece may be in the form of a cylinder or the frustum of a cone.

**centrifugal casting**. A casting made by pouring metal into a mold that is rotated or revolved.

**ceramic tools**. Cutting tools made from fused, sintered or cemented inorganic materials.

**cermet**. An organic binder, usually corn flour.

**cermet**. A powder metallurgy product consisting of ceramic particles bonded with a metal.

**C-frame press**. Same as *grip-frame press*.

**CG iron**. Same as *computer graphite cast iron*.

**chafing fatigue**. Fatigue initiated in a surface damaged by rubbing against another body. See *fatigue*.

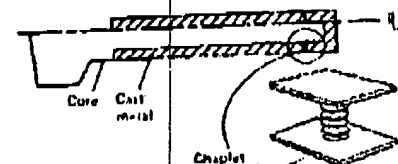
**chain-intermittent fillet welding**. Depositing a line of intermittent fillet welds on each side of a member at a joint so that the increments on one side are essentially opposite those on the other. Contrast with *staggered-intermittent fillet welding*.

**chamfer**. (1) A beveled surface to eliminate an otherwise sharp corner. (2) A relieved angular cutting edge at a tooth corner.

**chamfer angle**. (1) The angle between a reference surface and the bevel. (2) On a milling cutter, the angle between a beveled surface and the axis of the cutter.

**chamfering**. Making a sloping surface on the edge of a member. Also called *beveling*. See *bevel angle*.

**chaplet**. Metal support that holds a core in place within a mold; molten metal solidifies around a chaplet and fuses it into the finished casting.



**taconite.** A siliceous iron formation from which certain iron ores of the Lake Superior region are derived; consists chiefly of fine-grain silica mixed with magnetite and hematite.

**tailings.** The discarded portion of a crushed ore, separated during concentration.

**tandem die.** Same as *follow die*.

**tandem mill.** A rolling mill consisting of two or more stands arranged so that the metal being processed travels in a straight line from stand to stand. In continuous rolling, the various stands are synchronized so that the strip may be rolled in all stands simultaneously. Contrast with *single-stand mill*.

**tandem welding.** Arc welding in which two or more electrodes are in a plane parallel to the line of travel.

**tangent bending.** Forming one or more identical bends having parallel axes by wiping sheet metal around one or more radius dies in a single operation. The sheet, which may have side flanges, is clamped against the radius die, then made to conform to the radius die by pressure from a rocker-plunger die that moves along the periphery of the radius die.

**tangent modulus.** See *modulus of elasticity*.

**tank voltage.** The total voltage between the anode and cathode of a plating bath or electrolytic cell during electrolysis. It is equal to the sum of: (a) the equilibrium reaction potential, (b) the *IR* drop and (c) the electrode potentials.

**tap.** A cylindrical or conical thread-cutting tool with one or more cutting elements having threads of a desired form on the periphery. By a combination of rotary and axial motions, the tapping and cuts an internal thread, the tool deriving its principal support from the thread being produced.

**tap density.** The apparent density of a metal powder, obtained when the volume receptacle is tapped or vibrated during loading under specified conditions.

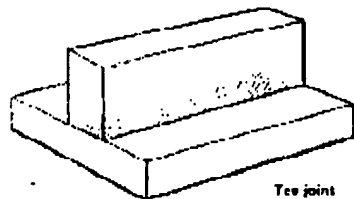
**tapping.** (1) Thinning the outlet of a melting furnace to remove molten metal. (2) Removing molten metal from a furnace. (3) Cutting internal threads with a tap.

**tarnish.** Surface discoloration of a metal caused by formation of a thin film of corrosion product.

**Taylor process.** A process for making extremely fine wire by inserting a piece of larger-diameter wire into a glass tube and stretching the two together at high temperature.

**three-bolt cohesive strength.** Fracture stress in a three tensile test. Often used instead of merely "relative strength" to avoid confusion among the several definitions of cohesive strength.

**tee joint.** A joint in which the members are oriented in the form of a T.



Tee joint

**tapping.** Pouring molten metal from a ladle into ingot molds. The term applies particularly to the specific operation of pouring either iron or steel into ingot molds.

**temper.** (1) In heat treatment, to reheat hardened steel or hardened cast iron to some temperature below the critical temperature for the purpose of decreasing hardness and increasing toughness. The process also is sometimes applied to normalized steel. (2) In tool steels, temper is sometimes but improperly used to denote carbon content. (3) In nonferrous alloys and in some ferrous alloys (steels that cannot be hardened by heat treatment), the hardness and strength produced by mechanical or thermal treatment, or both, and characterized by a certain structure, mechanical properties or reduction in area during cold working. (4) To maintain sand for casting molds with water.

**temper brittleness.** Brittleness that results when certain steels are held within, or are cooled slowly through, a certain range of temperature below the transformation range. This brittleness is manifested as an upward shift in ductile-to-brittle transition temperature, but only rarely produces a low value of reduction in area in a smooth-bar tension test of the unbrutted material.

**temper carbon.** Same as *annealing carbon*.

**temper color.** A thin, lightly adhering oxide skin (only a few molecules thick) that forms when steel is tempered at a low temperature, or for a short time, in air in a mildly oxidizing atmosphere. The color, which ranges from straw to blue depending on the thickness of the oxide skin, varies with both tempering time and temperature.

**temper rolling.** Light cold rolling of steel sheet. This operation is performed to improve flatness, to minimize the tendency toward formation of stretch strains and flutes, and to obtain the desired texture and mechanical properties.

**temper time.** In resistance welding, that part of the postweld interval during which the current is tunable for tempering or heat treatment.

**tensile strength.** In tensile testing, the ratio of maximum load to original cross-sectional area. Also called *ultimate strength*. Compare with *yield strength*.

**terminal phase.** A solid solution having a restricted range of compositions, one end of the range being a pure component of an alloy system.

**ternary alloy.** An alloy that contains three principal elements.

**terne.** An alloy of lead containing 3 to 15% tin, used as a hot dip coating for steel sheet or plate. Terne coatings, which are smooth and dull in appearance, give the steel better corrosion resistance and enhance its ability to be formed, soldered or painted.

**tertiary creep.** See *creep*.

**texture.** In a polycrystalline aggregate, the state of distribution of crystal orientations. In the usual sense, it is synonymous with *preferred orientation*.

**thermal analysis.** A method for determining transformations in a metal by noting the temperatures at which thermal arrests occur. These arrests are manifested by changes in slope of the plotted or mechanically traced heating and cooling curves. When such data are secured under nearly equilibrium conditions of heating and cooling, the method is commonly used for determining certain critical temperatures required for the construction of equilibrium diagrams.

**thermal electromotive force.** The electromotive force generated in a circuit containing two dissimilar metals when one junction is at a temperature different from that of the other. See also *thermopile*.

**thermal fatigue.** Fracture resulting from the presence of temperature gradients that vary with time in such a manner as to produce cyclic stresses in a structure.

**thermal shock.** The development of a steep temperature gradient and accompanying high stresses within a structure.

**thermal spraying.** A group of welding or allied processes in which finely divided metallic or nonmetallic materials are deposited in a molten or semimolten condition to form a coating. The coating material may be in the form of powder, ceramic mix, wire or molten materials. See also *flame spraying*, *plasma spraying*.

**thermal stresses.** Stresses in metal resulting from non-uniform temperature distribution.

**thermit reactions.** Strongly exothermic self-propagating reactions such as that where finely divided aluminum reacts with a metal oxide. A mixture of aluminum and iron oxide produces sufficient heat to melt steel, the filler metal being produced in the reaction.

**thermit welding.** Welding with heat produced by the reaction of aluminum with a metal oxide. Filler metal, if used, is obtained from reduction of an appropriate oxide.

**thermocouple.** A device for measuring temperatures consisting of lengths of two dissimilar metals or alloys that are electrically joined at one end and connected to a voltage-measuring instrument at the other end. When one junction is hotter than the other, a *thermal electromotive force* is produced that is roughly proportional to the difference in temperature between the hot and cold junctions.

**thermomechanical working.** A general term covering a variety of processes combining controlled thermal and deformation treatments to obtain synergistic effects such as improvement in strength without loss of toughness. Same as *thermo-mechanical treatment*.

**thief.** In electroplating, same as *robber*.

**Thomas converter.** A Bessemer converter having a basic bottom and lining, usually dolomite, and employing a basic slag.

**three-point bending.** Bending of a piece of metal, or a structural member, in which the object is placed across two supports and force is applied between and in opposition to them. See *V-bend die*.

**three-quarters hard.** A *temper* of nonferrous alloys and some ferrous alloys characterized by values of tensile strength and hardness about midway between those of *half hard* and *full hard* tempers.

**throat depth.** On a resistance-welding machine, the distance from the centerline of the electrode, or platen, to the nearest point of interference for the work.

**throat of a fillet weld.** (Theoretical) The distance from the beginning of the root of the joint perpendicular to the hypotenuse of the largest right triangle that can be inscribed within the fillet-weld cross section. (Actual) The shortest distance from the root of a fillet in its face. (Effective) The minimum distance from the root of the weld to its face, minus any reinforcement. See sketches accompanying *concave fillet weld*, *convex fillet weld*.

**through weld.** A nonpreferred term sometimes used to indicate a weld of substantial length made by melting through one member of a lap or tee joint and into the other member.

**throwing power.** The ability of a plating solution to produce a uniform metal distribution on an irregularly shaped cathode. Compare with *covering power*.

**tiger stripes.** Continuous bright lines on sheet or strip in the rolling direction.

**tight fit.** A loosely defined fit of slight negative allowance the assembly of which requires a light press or driving force.

**TIG welding.** Tungssten inert-gas welding; see preferred term, *gas tungsten-arc welding*.

**tilt boundary.** A subgrain boundary consisting of an array of edge dislocations.

**tilt mold.** A casting mold, usually a buck mold, that rotates from a horizontal to a vertical position during pouring, which reduces agitation and thus the formation and entrapment of oxides.

**tilt mold ingot.** An ingot made in a *tilt mold*.

**time quenching.** Interrupted quenching in which the time in the quenching medium is controlled.

**thinning.** Coating metal with a very thin layer of molten solder or brazing filler metal.

**tin pest.** A polymorphic modification of tin that causes it to crumble into a powder known as gray tin. It is generally accepted that the maximum rate of transformation occurs at about  $-40^{\circ}\text{C}$  ( $-40^{\circ}\text{F}$ ), but transformation can occur at as high as about  $13^{\circ}\text{C}$  ( $55^{\circ}\text{F}$ ).

**tin sweat.** See *swell*.

**tin tossing.** Oxidizing impurities in molten tin by pouring it from one vessel to another in air, forming a dross that is mechanically separable.

**TIR.** Abbreviation for *total indicator reading*.

**TIV.** Abbreviation for *total indicator variation*.

**too crack.** A base-metal crack at the toe of weld.

**toe of weld.** The junction between the face of a weld and the base metal. See sketch accompanying *fillet weld*.

**toggle press.** A mechanical press in which the slide is actuated by one or more toggle links or mechanisms.

**tolerance.** The specified permissible deviation from a specified nominal dimension, or the permissible variation in size or other quality characteristic of a part.

**tolerance limits.** The boundaries that define the range of permissible variation in size or other quality characteristic of a part.

**tool steel.** Any of a class of carbon and alloy steels commonly used to make tools. Tool steels are characterized by high hardness and resistance to abrasion, often accompanied by high toughness and resistance to softening at elevated temperature. These attributes are generally attained with high carbon and alloy contents.

**tooth.** (1) A projection on a multipoint tool (such as on a saw, milling cutter or file) designed to produce cutting. (2) A projection on the periphery of a wheel or segment thereof (as on a gear, spline or sprocket, for example), designed to engage another mechanism and thereby transmit force or motion, or both. A similar projection on a flat member such as a rack.

**tooth point.** On a face mill, the chamfered cutting edge of the blade, to which a flat is sometimes added to produce a shaving effect and to improve finish. See sketch accompanying *face mill*.

**top-and-bottom process.** A process for separating copper and nickel, in which their molten sulfides are separated into two liquid layers by the addition of

# 18 TOOL MATERIALS

Reviewed and revised by Neil J. Culp, Carpenter Technology Corp.; Dennis D. Huffman, Timken Research; and R. J. Henry, University of Pittsburgh-Johnstown

Introduction and Overview .....	18-1	Cold Heading Tools .....	18-25
Tool Steels .....	18-1	Cold Extrusion Tools .....	18-25
Superhard Tool Materials .....	18-10	Tools for Drawing Wire, Bar and Tubing .....	18-27
Distortion in Tool Steels .....	18-14	Closed-Die Hot Forging Tools .....	18-28
Tool Materials for Special Applications .....	18-16	Hot Upset Forging Tools .....	18-29
Cutting Tools .....	18-16	Hot Extrusion Tooling .....	18-31
Shearing and Slitting Tools .....	18-17	Die-Casting Dies .....	18-31
Blanking and Piercing Dies .....	18-18	Powder-Compacting Tools .....	18-32
Press Forming Dies .....	18-19	Molds for Plastics and Rubbers .....	18-33
Deep Drawing Dies .....	18-20	Thread-Rolling Dies .....	18-35
Metalworking Rolls .....	18-21	Gages .....	18-35
Coining Dies .....	18-24	Selected References on Tool Materials .....	18-36

This section was condensed from Metals Handbook, Ninth Edition, Volume 3, Properties and Selection: Stainless Steels, Tool Materials and Special-Purpose Metals, pages 419 to 550. For more detailed information on the topics covered in this section, the reader is referred to the larger work. Additional articles on tool materials can be found within this volume in the following sections: Machining (Section 27), Heat Treating (Section 28), Joining (Section 30) and Metallography (Section 35). The reader should also consult the index to locate information not otherwise categorized. Listings of selected references and additional reading for further research are presented at the end of this section.

## Introduction and Overview

### Tool Steels

A TOOL STEEL is any steel used to make tools for cutting, forming or otherwise shaping a material into a part or component adapted to a definite use. The earliest tool steels were simple, plain carbon steels, but beginning in 1868, and to a greater extent early in the 20th century, many complex, highly alloyed tool steels were developed. Although plain carbon tool steels were first used and still are employed occasionally, it is the alloy tool steels containing, among other elements, relatively large amounts of tungsten, molybdenum, manganese, vanadium and chromium which have made it possible to meet increasingly severe service demands and to provide greater dimensional control and freedom from cracking during heat treatment. Many alloy tool steels are also widely used for machinery components and structural applications where particularly severe requirements must be met.

In service, most tools are subjected to extremely high loads that are applied rapidly. They must withstand these loads a great number of times without breaking or undergoing excessive wear or deformation. In many applications, tool steels must provide this capability under conditions that develop high temperatures in the tool. No single tool material combines maximum levels of wear resistance, toughness, and resistance to softening at elevated temperatures. Consequently, selection of the proper tool material for a given application often requires a trade-off to achieve the optimum combination of properties.

Most tool steels are wrought products, but pre-cement coatings can be used to advantage in some applications. The powder metallurgy (P/M) pro-

cess also is used in making tool steels, in both mill forms and near-net shapes. P/M tool steels may provide (a) more uniform carbide size and distribution in large sections and (b) special compositions that are difficult or impossible to produce by melting and casting and then mechanically working the cast product.

Tool steels are generally melted in small-tonnage electric arc furnaces to economically achieve composition tolerances, good cleanliness and precise control of melting conditions. Special refining and secondary remelting processes have been introduced to satisfy particularly difficult demands regarding tool steel quality and performance. Tool steels must have minimal decarburization held within carefully controlled limits. This requires that annealing be done by special procedures under closely controlled conditions.

The performance of a tool in service depends on proper design of the tool, accuracy with which the tool is made, selection of the proper tool steel and application of the proper heat treatment. A tool can perform successfully in service only when all four of these requirements have been fulfilled.

With few exceptions, all tool steels must be heat treated to develop specific combinations of wear resistance, resistance to deformation or breaking under high loads, and resistance to softening at elevated temperatures.

### CLASSIFICATION AND CHARACTERISTICS

Table 1 gives composition limits for the tool steels most commonly used today. Each group of tool steels of similar composition, application or mode of quenching is identified by a capital letter; within each group, individual tool steel types are assigned civic numbers.

### High Speed Steels

High speed steels are tool materials developed largely for use in high speed cutting-tool applications. There are two classifications of high speed steels: molybdenum high speed steels (group M) and tungsten high speed steels (group T). Group M steels constitute about 95% of all high speed steel produced in the United States.

Group M and group T high speed steels are equivalent in performance; the main advantage of group M steels is lower initial cost (approximately 40% lower than that of similar group T steels).

Molybdenum high speed steels and tungsten high speed steels are similar in many other respects, including hardenability. Typical applications for group M and group T steels include cutting tools of all kinds. Some grades are satisfactory for cold work applications, such as cold-chamber die inserts, thread-rolling dies, punches and blanking dies. Steels of the M40 series are used to make cutting tools for machining modern, very tough, high-strength steels.

For die inserts and punches, high speed steels sometimes are underhardened—that is, quenched from austenitizing temperatures lower than those recommended for cutting-tool applications—as a means of increasing toughness.

Molybdenum high speed steels contain molybdenum, tungsten, chromium, vanadium, cobalt and carbon as principal alloying elements. Group M steels have slightly greater toughness than group T steels at the same hardness. Otherwise, mechanical properties of the two groups are similar.

Increasing the carbon and vanadium contents of group M steels increases wear resistance; increasing the cobalt content improves red hard-

9

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☐ **FADED TEXT OR DRAWING**
- ☒ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☒ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER: \_\_\_\_\_**

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**